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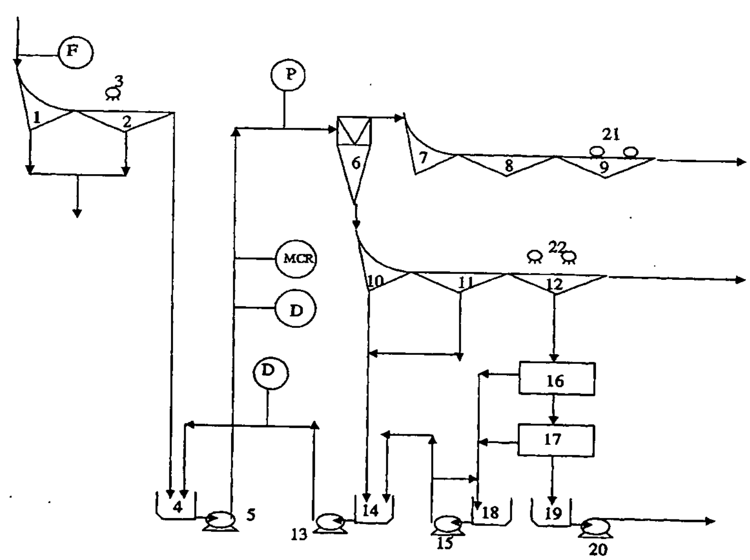

(57) Abstract: A method and apparatus for processing particulate material such as coal, and also for measuring the efficiency of separation of the coal is disclosed. Particulate material is supplied to a separator such as a heavy medium device containing a dense medium (6). A parameter of the device (6) indicative of separation cut point is measured. The parameter may be density of the medium, flow rate of material or pressure of feed as well as medium to coal ratio. Measurements of these parameters are made over a time period and, from the measurements, an induced value indicative of separating efficiency is determined. The induced value provides a measure of separation efficiency and also provides a value which can be compared with a predetermined value so that an alarm can be generated if the value departs from the predetermined value by a predetermined amount.

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METHOD AND APPARATUS FOR PROCESSING PARTICULATE MATERIAL

Field of the Invention

This invention relates to a method and apparatus for processing particulate material and, in particular, minerals and carbonaceous solids such as coal, iron ore, manganese, diamonds and other materials. The invention has particular application to the processing of coal, and will be further described in relation to the processing of coal. However, it should be understood that the invention is applicable to processing other materials including but not restricted to those mentioned above.

Background of the Invention

Raw coal is mined from the ground and is processed to provide a desirable commercial product. Raw coal includes a certain amount of gangue mineral content which, following combustion under standard conditions, leaves a solid ash residue.

For some applications (eg coke making) saleable coal most preferably has a fixed ash specification limit which is normally specified in contractual agreements between the producer and the purchaser. A typical example of an ash specification for high quality coking coal is 10% (air dried basis). If the ash level of produced coal increases above this level, the product may still be saleable but its price is deleteriously affected and/or some penalties for the producer may be incurred.

For other applications, saleable coal most preferably has a minimum or fixed specific energy content limit which is normally specified in contractual agreements between the producer and the purchaser. A typical example of an energy specification for high quality thermal coal is 6000 kCal/kg (net as received basis). If the specific energy level of produced coal decreases below this level, the product may still be saleable but its price is

deleteriously affected and/or some penalties for the producer may be incurred.

Raw coal after mining may be comminuted to a required size and separated into a particular particle size by a screen mesh type or other classification-type device to separate the raw coal into predetermined particle sizes defined by, for example, the screen aperture size of the screen separator and other operating characteristics such as state of screen wear, solids loading level, water addition rate etc.

The separated coal of the desired size is then supplied to a dense medium separator. There are a number of different dense medium separators currently in use depending on the size of particles being treated. For example, large lumps may be processed in heavy medium drums, heavy medium baths, heavy medium vessels, larcodems etc, and smaller but still coarse particles may be processed in heavy medium cyclones, heavy medium cycloids etc. Note that the words "heavy" and "dense" can be used interchangeably in this context. These types of heavy medium devices use a benign or inert finely ground powder of medium solids (such as magnetite or ferro-silicon) slurried in water to form a dense medium whose density can be automatically controlled by the proportion of solids in the slurry. Mixing the raw coal with the dense medium enables separation on the basis of its density relative to the density of the dense medium. For example, coal with an ash level of 10% may be separable from higher ash components of the raw coal by adding the raw coal to a dense medium of, for example, 1400kg/m^3. In this example, the 10% ash product coal might float clear of the higher ash material which might tend to sink in the dense medium. The material that floats would report to the overflow outlet of a separator and that which sinks would report to the underflow outlet.

For the specific case of a dense medium cyclone, it is separating efficiency of the coal particles that is often critical to maximising yield and recovery. The accepted industry standard for measuring efficiency is the partition coefficient curve with its characteristic D_{50} and Ep parameters. The D_{50} is the separating density of the particles and the Ep is a measure of the sharpness the separation (a higher value of Ep indicates more misplacement of particles and hence a lower efficiency).

Whilst the D_{50} of a separation is strongly related to the medium density, there are machine effects that lead to, almost invariably, the D_{50} being a little higher than the medium density. The difference between D_{50} and the medium is conventionally termed "offset". The extent to which it is greater is dependent on a number of parameters, including, but not limited to, medium density, dense medium cyclone pressure, raw coal feed rate, medium to coal ratio, and variations therein. The overall sharpness of separation is a strong function of variations in each of these parameters (medium density, pressure, feed rate and medium to coal ratio).

Measurement of the density of medium slurry is performed by, for example, nucleonic gauges or differential pressure transducers. Measurement of pressure of the material feeding a dense medium cyclone is performed with pressure transducers and the like, while plant feed rate is determined with weightometers on the conveyor belt feeding the plant. Medium to coal ratio is not conventionally measured on-line and plant feed rate may be used as a proxy. However, it is conceivable that such measurement may be made in the future when the measurement technology is developed.

Each of these parameters may be incorporated into individual control systems which attempt to maintain operational values of these parameters within acceptable

limits. However, control systems are imperfect and variations occur during normal industrial operations. Variations in the medium density, pressure, feed rate and medium to coal ratio cause separations to occur at densities (D_{50}'s) different from those desired. Momentary fluctuations that lead to higher D_{50}'s than desired will result in higher proportions of the raw coal being collected at the separator floats or overflow outlet. A momentary change in product quality will occur with a higher ash material separated. Similarly, the momentary changes in product quality will occur when fluctuations lead to lower D_{50}'s which result in decreases in the ash of the separated material.

Whilst plant control systems almost invariably allow overall consignment product within ash specification to be separated, this is often achieved at the expense of yield and recovery. Maximum yield or recovery at a given product quality is achieved when fluctuations in each of medium density, pressure,feed rate and medium to coal ratio are minimised.

Typically, in order to obtain an E_P value, samples of the material which are being processed (such as coal) are acquired representatively following strict sampling procedures. This typically involves concurrent taking of a sample from the feed line to the separator, and also samples which have reported to product and reported to reject. Those three samples are then forwarded to a laboratory for analysis and raw data is obtained which is then analysed to produce the partition curve. Typically, the taking of the samples involves a number of people who may, for example, take sample increments over a nine hour period. Furthermore, typically the analysis of the samples and then the preparation of the partition curve may take several weeks. Thus, results are not available in accordance with the prior art teaching for some weeks or the like after the sample material is actually

acquired.

Summary of the Invention

The object of the invention is to provide a method and apparatus for processing particulate material, such as coal, in which yield or recovery losses can be reduced.

The present invention provides a method of processing particulate material, including the steps of:

supplying the particulate material to a separator;

monitoring a parameter or parameters of the separator indicative of a separation value of the material;

determining from said parameter an induced value indicative of the separating efficiency of the material that passed through said separator;

comparing said value with a predetermined value; and

generating an alarm condition if the said value departs from the predetermined value by a predetermined amount.

Thus, according to the invention, if the effective separating efficiency departs from the required separating efficiency by a predetermined amount an alarm signal is generated. This enables remedial action to be taken to correct whatever fault has caused the change in the separating efficiency of the dense medium device, thereby returning the separating efficiency to its desired level to decrease the loss due to fluctuations in the separating density of the material. In other words, the fluctuation cycle of the cut point and other partition coefficient-based characteristics can be more quickly responded to so as to reduce both the magnitude and time of the fluctuations to reduce yield and recovery losses caused by those fluctuations.

The separation value may comprise the separating density if the separator is a medium dense separator or may be size of material if the separator is a classifying separator based on size of the material.

Preferably the separator comprises a heavy medium device containing a dense medium.

Preferably the step of determining the induced value comprises determining an induced set of values indicative of the separating efficiency of the material that passed through the device, the step of comparing said value comprises comparing said set of values with a predetermined range for the set of values, and the step of generating the alarm condition comprises generating the alarm condition if the said set of values departs from the predetermined range for the set of values by a predetermined amount.

The set of values may be in the form of a partition coefficient curve and parameters derived therefrom.

In the preferred embodiment of the invention, the parameter which is monitored is the actual density of the medium.

However, in another embodiment, the parameter is pressure of the medium and particle mixture which is supplied to the device.

In a still further embodiment the parameter is the feed rate of the medium and particle mixture supplied to the device. A practical proxy for this is the overall processing plant feed rate.

In a still further embodiment the parameter is the ratio of volume or mass flow rate of medium to the volume or mass flow rate of the raw coal, commonly referred to as

"Medium to Coal Ratio". Direct measurement of this parameter is preferable, but a practical proxy is processing plant feed rate.

In a still further embodiment of the invention, two or more of the medium density, pressure of the medium and particle mixture, feed rate of the medium and particle mixture, and Medium to Coal Ratio are monitored.

In the preferred embodiment of the invention, the density of the medium is measured at predetermined time intervals, and for a predetermined time period, the number of measurements at each measured value is determined to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and said set of values characterising separating efficiency is determined as a medium induced partition coefficient curve and/or a parameter derived therefrom, for example medium induced Ep value (MIEp value) by taking the absolute value of the difference in density at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the MIEp value with the said predetermined value, or medium induced partition coefficient curve with a predetermined partition coefficient curve. When making the necessary measurements to calculate the said separating efficiency characteristics, the predetermined time interval should be small in relation to the predetermined time period. A further assumption implicit in this approach is that offset is constant over the range of density values encountered.

In the other embodiments of the invention a feed rate induced partition coefficient curve and/or a parameter derived therefrom, for example feed rate induced Ep(FRIEp) value is determined in the same manner from the feed rate measurements made over the predetermined time period.

However a theoretical and/or empirical calibration will be required to convert feed rate variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. However, a pseudo-feed rate induced partition coefficient curve and derivatives therefrom may be calculated without the need for a theoretical and/or empirical calibration. In such case the cumulative normalised frequency distribution curve would be plotted against feed rate as the abscissa and a pseudo FRIEp calculated in a similar manner to MIEp. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment if the parameter is feed rate. In the case of measuring the pressure of the medium and particle mixture, a pressure induced partition coefficient curve and a derived pressure induced Ep(PIEp) value is determined so that individual values over the predetermined time period are used to calculate a cumulative normalised frequency distribution of separating densities, giving the length of time spent at each separating density. Once again a theoretical and/or empirical calibration is required to convert pressure measurements to separating density (D_{50}). In a similar manner to the case for feed rate, a pseudo curve and pseudo PIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment if the parameter is pressure. In the case of measuring the Medium to Coal Ratio of the medium and particle mixture, a Medium to Coal Ratio induced partition coefficient curve and a derived Medium to Coal Ratio induced Ep(MCRIEp) value is determined so that individual values over the predetermined time period are used to calculate a cumulative normalised frequency distribution of separating densities, giving the length of time spent at each separating density. Once again a theoretical and/or empirical calibration is required to

convert Medium to Coal Ratio measurements to separating density (D_{50}). In a similar manner to the case for feed rate and pressure, a pseudo curve and pseudo MCRIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment if the parameter is medium to coal ratio.

The present invention may be said to reside in an apparatus for processing particulate material, comprising:

means for supplying the particulate material to a separator;

means for monitoring a parameter of the separator indicative of a separation value of the material;

processing means for determining from said parameter an induced value indicative of the separating efficiency of the material that passed through said separator;

comparing means for comparing said value with a predetermined value; and

alarm means for producing an alarm condition if the said value departs from the predetermined value set by a predetermined amount.

Preferably the separator comprises a heavy medium device.

Preferably the processing means determines from said parameter an induced set of values indicative of the separating efficiency of the material that passed through the device, the comparing means compares the said value set with a predetermined value set and the alarm means is for producing the alarm condition if the set of values departs from the predetermined value set by a predetermined amount.

The set of values may be in the form of an induced partition coefficient curve and parameters derived therefrom.

In the preferred embodiment of the invention, the monitoring means measures the density of the medium at predetermined time intervals, and for a predetermined time period, such that the predetermined time intervals are small compared to the predetermined time and the processing means determines the number of measurements at each measured value to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and determines said value set as a medium induced partition coefficient curve and/or parameters derived therefrom, for example medium induced Ep value (MIEp value) by taking the absolute value of the difference in relative density at the 75th and 25th percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the partition coefficient curve and parameters derived therefrom, for example, MIEp value set with the said predetermined value set.

In the other embodiments of the invention a feed rate induced partition coefficient curve and parameters derived therefrom, for example Ep(FRIEp) value set is determined in a similar manner from the feed rate measurements made over the predetermined time period. As feed rate to dense medium separators is not commonly measured directly, overall processing plant feed rate is used as a proxy. However a theoretical and/or empirical calibration will be required to convert feed rate variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. However, a pseudo-feed rate induced partition coefficient curve and derivatives there from may be calculated without the need for a theoretical and/or empirical calibration. In such case the cumulative normalised frequency distribution curve would be plotted against feed rate as the abscissa

and a pseudo FRIEp calculated in a similar manner to MIEp. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the pressure of the medium and particle mixture, a pressure induced partition coefficient curve and parameters derived therefrom, for example, pressure induced Ep(PIEp) value set is determined in a similar manner from the pressure measurements made over the predetermined time period. However a theoretical and/or empirical calibration will be required to convert pressure variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. In a similar manner to the case for feed rate, a pseudo curve and pseudo PIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the Medium to Coal Ratio, a Medium to Coal Ratio induced partition coefficient curve and parameters derived therefrom, for example, Medium to Coal Ratio induced Ep(MCRIEp) value set is determined in a similar manner from the Medium to Coal Ratio measurements made over the predetermined time period. However a theoretical and/or empirical calibration will be required to convert Medium to Coal Ratio variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. In a similar manner to the case for feed rate and pressure, a pseudo curve and pseudo MCRIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment.

A second aspect of the invention provides a method of determining the efficiency of separation of particulate

material supplied to a separator, comprising the steps of:

monitoring a parameter of the separator indicative of a separation value of the material;

determining from said parameter an induced value indicative of the separating efficiency of the material that pass through the separator; and

using the induced value to provide a measure of the efficiency of separation.

Thus, according to this aspect of the invention, because a parameter of the separator, rather than the material which is being separated is monitored, the data required to determine efficiency can be acquired much more quickly and also much less expensively because the equipment needed to measure the parameters of the separator, rather than analysis actual sample material can be performed much quicker and less expensively. In addition, in the case of medium induced Ep, the density measurements required are readily available as they comprise those used to as part of a density control system. The same can be said for pressure and feed rate. Thus, an efficiency measure of the separation of the coal can be produced almost in real time, thereby enabling remedial action to be taken should the efficiency of separation deteriorate. This in turn enables a processing plant for processing the material to be corrected where necessary to ensure that separation is efficiently performed, thereby producing better product and economic results.

Preferably the step of determining the induced value comprises determining an induced set of values indicative of the separating efficiency of the material that passed through the device, the step of comparing said value comprises comparing said set of values with a predetermined range for the set of values, and the step of generating the alarm condition comprises generating the alarm condition if the said set of values departs from the predetermined range for the set of values by a

predetermined amount.

The set of values may be in the form of an induced partition coefficient curve and parameters derived therefrom.

In the preferred embodiment of the invention, the parameter which is monitored is the actual density of the medium.

However, in another embodiment, the parameter is pressure of the medium and particle mixture which is supplied to the device.

In a still further embodiment the parameter is the feed rate of the medium and particle mixture supplied to the device. A practical proxy for this is the overall processing plant feed rate.

In a still further embodiment the parameter is the ratio of volume or mass flow rate of medium to the volume of mass flow rate of the raw coal, commonly referred to as "Medium to Coal Ratio". Direct measurement of this parameter is preferable, but a practical proxy is processing plant feed rate.

In a still further embodiment of the invention, two or more of the medium density, pressure of the medium and particle mixture, feed rate of the medium and particle mixture, and Medium to Coal Ratio are monitored.

In the preferred embodiment of the invention, the density of the medium is measured at predetermined time intervals, and for a predetermined time period, the number of measurements at each measured value is determined to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and said set of values characterising separating

efficiency is determined as a medium induced partition coefficient curve and/or a parameter derived therefrom, for example medium induced Ep value (MIEp value) by taking the absolute value of the difference in density at the 75th and 25th percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the MIEp value with the said predetermined value, or medium induced partition coefficient curve with a predetermined partition coefficient curve. When making the necessary measurements to calculate the said separating efficiency characteristics, the predetermined time interval should be small in relation to the predetermined time period. A further assumption implicit in this approach is that offset is constant over the range of density values encountered.

In the other embodiments of the invention a feed rate induced partition coefficient curve and/or a parameter derived therefrom, for example feed rate induced Ep(FRIEp) value is determined in the same manner from the feed rate measurements made over the predetermined time period. However a theoretical and/or empirical calibration will be required to convert feed rate variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. However, a pseudo feed rate induced partition coefficient curve may be derived without the need for a theoretical and/or empirical calibration. In such case the cumulative normalised frequency distribution curve would be plotted against feed rate as abscissa and the pseudo FRIEp calculated in a similar way to FRIEp. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the pressure of the medium and particle mixture, a pressure induced partition coefficient curve and a derived pressure

induced Ep(PIEp) value is determined so that individual values over the predetermined time period are used to calculate a cumulative normalised frequency distribution of separating densities, giving the length of time spent at each separating density. Once again a theoretical and/or empirical calibration is required to convert pressure measurements to separating density (D_{50}). However, a pseudo pressure induced partition coefficient curve may be derived without the need for a theoretical and/or empirical calibration. In such case the cumulative normalised frequency distribution curve would be plotted against feed rate as abscissa and the pseudo PIEp calculated in a similar way to PIEp. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the Medium to Coal Ratio of the medium and particle mixture, a Medium to Coal Ratio induced partition coefficient curve and a derived Medium to Coal Ratio induced Ep(MCRIEp) value is determined so that individual values over the predetermined time period are used to calculate a cumulative normalised frequency distribution of separating densities, giving the length of time spent at each separating density. Once again a theoretical and/or empirical calibration is required to convert Medium to Coal Ratio measurements to separating density (D_{50}). However, a pseudo Medium to Coal Ratio induced partition coefficient curve may be derived without the need for a theoretical and/or empirical calibration. In such case the cumulative normalised frequency distribution curve would be plotted against feed rate as abscissa and the pseudo MCRIEp calculated in a similar way to MCRIEp. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment.

This aspect of the invention also provides using the measure of efficiency determined according to the above

method to adjust a processing plant to more efficiently separate the material.

This aspect of the invention also provides an apparatus for processing particulate material, comprising:

means for supplying the particulate material to a separator;

means for monitoring a parameter of the separator indicative of a separation value of the material; and

processing means for determining from said parameter an induced value indicative of the separating efficiency of the material that pass through said separator to thereby provide a measure of the efficiency of the apparatus.

Preferably the separator comprises a heavy medium device.

Preferably the processing means determines from said parameter an induced set of values indicative of the separating efficiency of the material that passed through the device, the comparing means compares the said value set with a predetermined value set and the alarm means is for producing the alarm condition if the set of values departs from the predetermined value set by a predetermined amount.

The set of values may be in the form of a partition coefficient curve and parameters derived therefrom.

In the preferred embodiment of the invention, the monitoring means measures the density of the medium at predetermined time intervals, and for a predetermined time period, and the processing means determines the number of measurements at each measured value to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and determines said value set as a medium induced partition coefficient curve and/or parameters derived therefrom, for

example medium induced Ep value (MIEp value) by taking the absolute value of the difference in relative density at the 75th and 25th percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the partition coefficient curve and parameters derived therefrom, for example, MIEp value set with the said predetermined value set.

In the other embodiments of the invention a feed rate induced partition coefficient curve and parameters derived therefrom, for example Ep(FRIEp) value set is determined in a similar manner from the feed rate measurements made over the predetermined time period. As feed rate to dense medium separators is not commonly measured directly, overall processing plant feed rate is used as a proxy. However a theoretical and/or empirical calibration will be required to convert feed rate variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. However, a pseudo-feed rate induced partition coefficient curve and derivatives there from may be calculated without the need for a theoretical and/or empirical calibration. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the pressure of the medium and particle mixture, a pressure induced partition coefficient curve and parameters derived therefrom, for example, pressure induced Ep(PIEp) value set is determined in a similar manner from the pressure measurements made over the predetermined time period. However a theoretical and/or empirical calibration will be required to convert pressure variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. In a similar manner to the case for feed rate, a

pseudo curve and pseudo PIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment. In the case of measuring the Medium to Coal Ratio, a Medium to Coal Ratio induced partition coefficient curve and parameters derived therefrom, for example, Medium to Coal Ratio induced Ep(MCRIEp) value set is determined in a similar manner from the Medium to Coal Ratio measurements made over the predetermined time period. However a theoretical and/or empirical calibration will be required to convert Medium to Coal Ratio variation to D_{50} variation so as to produce a cumulative normalised frequency distribution of separating densities and so provide the length of time spent at each separating density. In a similar manner to the case for feed rate and pressure, a pseudo MCRIEp may be calculated. As the pseudo variation on the concept does not require calibration, is easier to measure and use, and it is the preferred method of efficiency assessment.

Conventionally, the partition coefficient curve is measured by determining how coal particles entering the separating device separate. This invention separates the impact of separator design, operational configuration and wear condition from the impact of processing operating variables such as medium density, pressure and flow rates. In essence, the invention separates in to distinct measurable entities inefficiencies due to variations in process variables such as medium density, pressure and flow rates. The overall separating Ep for coal will be the combination of the Ep due to the separator design, configuration and wear condition (which has a relatively slow temporal change rate), Ep due to medium density variation, Ep due to pressure variation, Ep due to feed rate variation etc. The later factors will have a much higher temporal change rate. Furthermore, whilst conventional measurement of coal partition coefficient curve is laborious and time consuming, quantification of

the process variables, particularly medium density, pressure and feed rate is rapid, easy and cheap to achieve on-line utilising systems and equipment commonly existing in modern processing facilities.

Brief Description of the Drawings

A preferred embodiment of the invention will be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is an illustrative diagram illustrating apparatus for processing coal;

Figure 2 is a block diagram illustrating the operation of the preferred embodiment of the invention;

Figure 3 is a graph showing the accumulative normalised frequency distribution for an ideal situation; and

Figure 4 is a graph of the type of Figure 3 exemplifying what may occur in actual practice.

Detailed Description of the Preferred Embodiments

The following is a specific example of a generic dense medium cyclone circuit. It is given as a means only of explaining how the invention can be applied and does not limit the coverage of the invention to the specific example given.

Prior to entering the process depicted in Figure 1, raw coal may be reduced to 50mm top size. With reference to Figure 1, raw coal is separated on a sieve bend 1 followed by a vibratory screen 2 with wash water addition 3. This device removes fine particles, typically less than 2-0.2mm, from the raw coal and all the undersize is processed in devices not mentioned here. The oversize material gravitates to sump 4 from which it is pumped 5 to the dense medium cyclone 6. It will be noted on Figure 1 that dense medium is added to the coarse coal particles in the dense medium cyclone feed sump 4. The coarse raw coal is separated in the dense medium cyclone 6 to produce a

lower ash product and a higher ash reject. The product is separated from the dense medium on sieve bend 7 and drain 8 and rinse screen 9. The sieve bend and drain screens remove the bulk of the dense medium which can then recycled to the dense medium sump 14. The rinse screen 9 uses water addition 21, 22 (dirty and clarified) to aid the removal of medium adhering to the coal particles. Rinse screen underflow is significantly diluted and must be concentrated such that the water is removed before it can be reused in the operation of the dense medium cyclone. Similar sieve bend 10, drain 11 and rinse 12 screen recovery of dense medium occurs for the dense medium cyclone underflow material.

The diluted dense medium is dewatered with magnetic separators 16 and 17. The recovered dense medium is passed to the over-dense sump 18 from where it is pumped 15 to the dense medium sump 14. The separated water is recycled for use elsewhere in the plant, including water addition to the screening operations described above.

Also shown on Figure 1 are the locations of measuring devices for medium density D, pressure P, Medium to Coal Ratio (MCR) and feed rate F.

It should be noted once again that this is a very brief and simplified description of the generic circuitry for coal processing.

The density of the dense medium supplied to the mixture with the particulate material is measured with a nucleonic or differential pressure transducer D. Two indicative locations for measuring this parameter are indicated on Figure 1.

The pressure of the medium density and particulate mixture supplied to the dense medium cyclone is also measured by pressure transducer P.

The location of Medium to Coal Ratio measurement is also shown and could be measured by the emerging electro-impedance spectrometry technology which is not yet common place in the industry.

In the preferred embodiment of the invention, the density measurements made by the nucleonic or differential pressure transducer D are used to generate an alarm condition, should the medium induced partition coefficient curve and/or parameters derived therefrom change from the desired values so that remedial action can be taken to restore the desired density control and thereby minimise losses caused by fluctuations or variations in the density of the medium density. However, as has been previously described, the pressure measurements, Medium to Coal Ratio measurements or feed rate measurements may be used in combination with the density measurements or instead of the density measurements in order to continually monitor the fluctuations in medium induced partition coefficient curve and/or parameters derived therefrom to enable the alarm condition to be generated and remedial action immediately taken to restore the required level of control of the dense medium separation.

With reference to Figure 2, the density measurements from the nucleonic or differential pressure transducer D are fed to a processor 50, typically maintained in, but not limited to, the coal plant operation room when in the desired location, or any other suitable location. The pressure and feed rate measurements from the pressure transducer P and weightometers F are also fed to the processor 50. Medium to Coal Ratio measurements from electro-impedance spectrometry technology would also be fed to the processor 50.

According to the preferred embodiment of the invention, measurements are read frequently, for example every 1

minute, and those measurements are taken over a predetermined time period of, for example 30 minutes to 2.5 hours, may be used to determine the value set for comparison with the predetermined value set in order to determine whether the alarm condition needs to be generated.

Table 1 below shows exemplary measurements which may be taken over a time period of 9 hours and used for processing in the processor 50.

Table 1

Time	Density	Time	Density	Time	Density
7:21:54	1571.48	7:49:28	1577.82	8:17:02	1530.05
7:22:29	1571.29	7:50:04	1568.54	8:17:38	1523.18
7:23:05	1568.14	7:50:40	1562.07	8:18:14	1520.75
7:23:41	1565.46	7:51:16	1554.97	8:18:50	1514.17
7:24:17	1560.24	7:51:52	1549.87	8:19:26	1523.2
7:24:53	1557.2	7:52:27	1544.62	8:20:02	1533.14
7:25:29	1557.36	7:53:03	1537.75	8:20:38	1532.79
7:26:05	1555.98	7:53:39	1526.34	8:21:14	1528.03
7:26:41	1552.94	7:54:15	1522.88	8:21:50	1521.08
7:27:17	1541.99	7:54:51	1521.17	8:22:25	1522.11
7:27:53	1535.55	7:55:27	1522.5	8:23:01	1520.89
7:28:29	1530.52	7:56:03	1521.06	8:23:37	1510.81
7:29:05	1524.52	7:56:39	1523.56	8:24:13	1498.6
7:29:41	1518.36	7:57:15	1524.7	8:24:49	1486.71
7:30:17	1508.26	7:57:51	1526.32	8:25:25	1464.58
7:30:53	1509.17	7:58:27	1525.81	8:26:01	1455.65
7:31:29	1524.88	7:59:03	1524.35	8:26:37	1446.62
7:32:05	1550.78	7:59:39	1522.54	8:27:13	1442.86
7:32:41	1563.68	8:00:15	1518.14	8:27:49	1463.41
7:33:17	1565.84	8:00:51	1513.85	8:28:25	1488.11
7:33:53	1563.41	8:01:27	1514.7	8:29:01	1508.38
7:34:29	1555.61	8:02:03	1525.43	8:29:37	1518.74
7:35:05	1552.5	8:02:39	1533.79	8:30:13	1529.76
7:35:41	1544.18	8:03:15	1543.44	8:30:49	1537.17
7:36:17	1539.94	8:03:51	1549.9	8:31:25	1536.6
7:36:53	1532.69	8:04:27	1548.61	8:32:01	1533.14
7:37:28	1526.97	8:05:03	1547.15	8:32:37	1525.17
7:38:04	1521.66	8:05:39	1545.95	8:33:13	1524.33
7:38:40	1519.88	8:06:15	1543.43	8:33:49	1522.95
7:39:16	1516.89	8:06:51	1539.92	8:34:25	1521.1
7:39:52	1501.46	8:07:26	1536.66	8:35:01	1519.82
7:40:28	1480.52	8:08:02	1531.5	8:35:37	1518.87
7:41:04	1471.89	8:08:38	1525.81	8:36:13	1517.45
7:41:40	1473.86	8:09:14	1519.66	8:36:49	1515.65
7:42:16	1490.65	8:09:50	1513.08	8:37:24	1515.39
7:42:52	1511.69	8:10:26	1512.24	8:38:00	1518.52
7:43:28	1524.97	8:11:02	1515.62	8:38:36	1528.5
7:44:04	1548.59	8:11:38	1530.43	8:39:12	1541.7
7:44:40	1580.46	8:12:14	1546.59	8:39:48	1540.91
7:45:16	1595.15	8:12:50	1547.2	8:40:24	1540.16
7:45:52	1611.78	8:13:26	1546.7	8:41:00	1537.56
7:46:28	1618.13	8:14:02	1545.82	8:41:36	1532.68
7:47:04	1622.66	8:14:38	1543.18	8:42:12	1523.01
7:47:40	1622.54	8:15:14	1541.39	8:42:48	1514.37
7:48:16	1618.63	8:15:50	1536.15	8:43:24	1512.51
7:48:52	1587.34	8:16:26	1532.97	8:44:00	1515.4

Table 1. Cont (a)

Time	Density	Time	Density	Time	Density
8:44:36	1528.01	9:12:10	1528.41	9:39:44	1590
8:45:12	1549.12	9:12:46	1533.87	9:40:20	1583.98
8:45:48	1566.6	9:13:22	1566.18	9:40:56	1583.16
8:46:24	1591.5	9:13:58	1591.25	9:41:32	1579.93
8:47:00	1582.88	9:14:34	1573.89	9:42:08	1577.61
8:47:36	1579.59	9:15:10	1572.24	9:42:44	1578.47
8:48:12	1572.02	9:15:46	1570.41	9:43:20	1578.01
8:48:48	1567	9:16:22	1562.4	9:43:56	1573.13
8:49:24	1566.1	9:16:58	1561.26	9:44:32	1567.29
8:50:00	1563.72	9:17:34	1560.41	9:45:08	1564.71
8:50:36	1559.59	9:18:10	1559.66	9:45:44	1560.32
8:51:12	1559.19	9:18:46	1558.07	9:46:20	1554.06
8:51:48	1553.49	9:19:22	1548.05	9:46:56	1545.22
8:52:23	1549.28	9:19:58	1542.21	9:47:32	1536.95
8:52:59	1543.38	9:20:34	1538.82	9:48:08	1531.57
8:53:35	1538.93	9:21:10	1531.64	9:48:44	1520.58
8:54:11	1531.98	9:21:46	1524.34	9:49:20	1514.83
8:54:47	1527.54	9:22:21	1521.97	9:49:56	1514.19
8:55:23	1520.06	9:22:57	1515.61	9:50:32	1526.09
8:55:59	1518.66	9:23:33	1509.27	9:51:08	1541.41
8:56:35	1512	9:24:09	1508.49	9:51:44	1544.95
8:57:11	1510.46	9:24:45	1517.54	9:52:19	1544.7
8:57:47	1516.8	9:25:21	1535.31	9:52:55	1543.15
8:58:23	1538.85	9:25:57	1546.61	9:53:31	1536.54
8:58:59	1556.67	9:26:33	1554.74	9:54:07	1532.97
8:59:35	1566.7	9:27:09	1562.12	9:54:43	1522.12
9:00:11	1560.83	9:27:45	1564.06	9:55:19	1501
9:00:47	1555.12	9:28:21	1574.38	9:55:55	1504.86
9:01:23	1553.18	9:28:57	1574.84	9:56:31	1515.49
9:01:59	1549.47	9:29:33	1566.97	9:57:07	1554.31
9:02:35	1549.32	9:30:09	1566.28	9:57:43	1594.72
9:03:11	1550.1	9:30:45	1561.85	9:58:19	1581.69
9:03:47	1551.14	9:31:21	1558.69	9:58:55	1578.96
9:04:23	1552.42	9:31:57	1549.33	9:59:31	1577.34
9:04:59	1550.17	9:32:33	1546.23	10:00:07	1571.28
9:05:35	1541.97	9:33:09	1539.1	10:00:43	1570.39
9:06:11	1539.53	9:33:45	1533.81	10:01:19	1569.2
9:06:47	1534.76	9:34:21	1525.34	10:01:55	1569.02
9:07:22	1532.91	9:34:57	1516.18	10:02:31	1568.81
9:07:58	1525.5	9:35:33	1507.14	10:03:07	1564.34
9:08:34	1520.57	9:36:09	1505.81	10:03:43	1557.1
9:09:10	1518.59	9:36:45	1518.01	10:04:19	1551.67
9:09:46	1512.5	9:37:20	1531.86	10:04:55	1547.28
9:10:22	1510.54	9:37:56	1554.32	10:05:31	1531.81
9:10:58	1509.42	9:38:32	1563.99	10:06:07	1530.39
9:11:34	1511.09	9:39:08	1576.83	10:06:43	1519.56

Table 1. Cont (b)

Time	Density	Time	Density	Time	Density
10:07:18	1514.21	10:34:53	1510.72	11:02:27	1508.63
10:07:54	1512.76	10:35:29	1529.87	11:03:03	1508.76
10:08:30	1519.42	10:36:05	1554.8	11:03:39	1510.07
10:09:06	1530.69	10:36:41	1568.52	11:04:15	1521.7
10:09:42	1544.09	10:37:16	1570	11:04:51	1534.43
10:10:18	1550.81	10:37:52	1569.09	11:05:27	1560.22
10:10:54	1550.33	10:38:28	1567.52	11:06:03	1570.76
10:11:30	1548.65	10:39:04	1567.26	11:06:39	1581.18
10:12:06	1542.8	10:39:40	1576.85	11:07:14	1575.61
10:12:42	1541.02	10:40:16	1581.32	11:07:50	1571.99
10:13:18	1537.74	10:40:52	1578.59	11:08:26	1570.68
10:13:54	1530.19	10:41:28	1570.35	11:09:02	1570.05
10:14:30	1528.48	10:42:04	1568.94	11:09:38	1567.74
10:15:06	1528.96	10:42:40	1567.89	11:10:14	1567.49
10:15:42	1529.01	10:43:16	1563.15	11:10:50	1566.11
10:16:18	1529.75	10:43:52	1561.13	11:11:26	1564.54
10:16:54	1530.13	10:44:28	1557.47	11:12:02	1561.24
10:17:30	1526.86	10:45:04	1555.12	11:12:38	1556.06
10:18:06	1521.66	10:45:40	1548.41	11:13:14	1549.86
10:18:42	1512.05	10:46:16	1540.41	11:13:50	1548.67
10:19:18	1510.26	10:46:52	1536.24	11:14:26	1533.39
10:19:54	1516.46	10:47:28	1524.24	11:15:02	1532.13
10:20:30	1529.82	10:48:04	1514.32	11:15:38	1527.21
10:21:06	1548.4	10:48:40	1513.28	11:16:14	1520.99
10:21:42	1561.94	10:49:16	1513.98	11:16:50	1514.18
10:22:17	1572.51	10:49:52	1531.54	11:17:26	1510
10:22:53	1569.01	10:50:28	1555.78	11:18:02	1510.96
10:23:29	1563.45	10:51:04	1563.7	11:18:38	1526.43
10:24:05	1562.52	10:51:40	1581.18	11:19:14	1548.92
10:24:41	1562.84	10:52:15	1590.08	11:19:50	1559.01
10:25:17	1564.35	10:52:51	1575.13	11:20:26	1559.8
10:25:53	1563.21	10:53:27	1573.64	11:21:02	1559.88
10:26:29	1561.2	10:54:03	1571.91	11:21:38	1557.63
10:27:05	1557.38	10:54:39	1569.33	11:22:13	1546.76
10:27:41	1554.12	10:55:15	1565.4	11:22:49	1522.9
10:28:17	1548.84	10:55:51	1565.82	11:23:25	1513.58
10:28:53	1545.58	10:56:27	1564.85	11:24:01	1501.81
10:29:29	1541.8	10:57:03	1563.39	11:24:37	1491.13
10:30:05	1539.85	10:57:39	1552.9	11:25:13	1511.48
10:30:41	1532.89	10:58:15	1544.92	11:25:49	1525.25
10:31:17	1526.82	10:58:51	1539.92	11:26:25	1547.59
10:31:53	1521.66	10:59:27	1533.3	11:27:01	1587.49
10:32:29	1519.89	11:00:03	1527.51	11:27:37	1615.3
10:33:05	1517.12	11:00:39	1526.38	11:28:13	1622.86
10:33:41	1508.57	11:01:15	1521.48	11:28:49	1623.28
10:34:17	1502.52	11:01:51	1518.69	11:29:25	1629.42

Table 1. Cont (c)

Time	Density	Time	Density	Time	Density
11:30:01	1627.97	11:57:35	1533.13	12:25:09	1509.23
11:30:37	1627.81	11:58:11	1550.87	12:25:45	1508.19
11:31:13	1610.47	11:58:47	1564.56	12:26:21	1520.57
11:31:49	1588.57	11:59:23	1587.36	12:26:57	1552.97
11:32:25	1580.53	11:59:59	1588.18	12:27:33	1568.78
11:33:01	1569.3	12:00:35	1581.23	12:28:09	1582.35
11:33:37	1561.99	12:01:11	1580.27	12:28:45	1574.04
11:34:13	1556.57	12:01:47	1578.79	12:29:21	1574.23
11:34:49	1546.36	12:02:23	1573.9	12:29:57	1571.59
11:35:25	1539.22	12:02:59	1567.59	12:30:33	1570.09
11:36:01	1532.02	12:03:35	1567.47	12:31:09	1553.8
11:36:37	1517.79	12:04:11	1567.51	12:31:45	1548.23
11:37:12	1504.21	12:04:47	1565.16	12:32:21	1548.2
11:37:48	1502.88	12:05:23	1554.35	12:32:57	1548.62
11:38:24	1508.15	12:05:59	1551.26	12:33:33	1547.59
11:39:00	1534.92	12:06:35	1544.48	12:34:09	1544.93
11:39:36	1542.27	12:07:10	1540.49	12:34:45	1538.97
11:40:12	1560.12	12:07:46	1528.76	12:35:21	1536.45
11:40:48	1561.58	12:08:22	1523.15	12:35:57	1530.41
11:41:24	1569.31	12:08:58	1520.7	12:36:33	1528.81
11:42:00	1602.57	12:09:34	1517.39	12:37:08	1525.79
11:42:36	1630.03	12:10:10	1510.07	12:37:44	1524.42
11:43:12	1623.15	12:10:46	1516.29	12:38:20	1512.65
11:43:48	1614.47	12:11:22	1531.6	12:38:56	1513.54
11:44:24	1611.08	12:11:58	1548.3	12:39:32	1525.07
11:45:00	1610.18	12:12:34	1552.85	12:40:08	1541.86
11:45:36	1608.51	12:13:10	1554.14	12:40:44	1563.75
11:46:12	1607.48	12:13:46	1554.02	12:41:20	1569.69
11:46:48	1598.75	12:14:22	1550.23	12:41:56	1569.45
11:47:24	1591.39	12:14:58	1542.21	12:42:32	1568.11
11:48:00	1585.69	12:15:34	1540.48	12:43:08	1561.01
11:48:36	1580.62	12:16:10	1533.69	12:43:44	1555.42
11:49:12	1576.74	12:16:46	1528.04	12:44:20	1551.74
11:49:48	1571.49	12:17:22	1507.88	12:44:56	1544.76
11:50:24	1565.49	12:17:58	1533.74	12:45:32	1540.13
11:51:00	1557.92	12:18:34	1544.35	12:46:08	1538.53
11:51:36	1549.07	12:19:10	1545.04	12:46:44	1529.59
11:52:11	1542.65	12:19:46	1542.53	12:47:20	1523.21
11:52:47	1540.23	12:20:22	1538.79	12:47:56	1519.08
11:53:23	1531.1	12:20:58	1539.43	12:48:32	1514.1
11:53:59	1529.78	12:21:34	1537.63	12:49:08	1513.1
11:54:35	1520.32	12:22:09	1533.7	12:49:44	1502.05
11:55:11	1517.97	12:22:45	1526.92	12:50:20	1526.46
11:55:47	1513.61	12:23:21	1522.59	12:50:56	1586.25
11:56:23	1513.7	12:23:57	1519.81	12:51:32	1620.56
11:56:59	1515.11	12:24:33	1516.35	12:52:07	1614

Table 1. Cont (d)

Time	Density	Time	Density	Time	Density
12:52:43	1601.39	13:20:18	1558.59	13:47:52	1526.17
12:53:19	1601.76	13:20:54	1557.39	13:48:28	1521.69
12:53:55	1603.86	13:21:30	1556.18	13:49:04	1512.85
12:54:31	1602.71	13:22:05	1555.23	13:49:40	1511.38
12:55:07	1601.32	13:22:41	1551.83	13:50:16	1515.48
12:55:43	1593.09	13:23:17	1540.64	13:50:52	1541.15
12:56:19	1585.93	13:23:53	1540.09	13:51:28	1559.98
12:56:55	1579.51	13:24:29	1538.82	13:52:03	1564.4
12:57:31	1574.21	13:25:05	1533.68	13:52:39	1565.1
12:58:07	1566.15	13:25:41	1526.91	13:53:15	1564.1
12:58:43	1556.04	13:26:17	1521.88	13:53:51	1549.58
12:59:19	1554.77	13:26:53	1513.14	13:54:27	1538.78
12:59:55	1553.03	13:27:29	1508.49	13:55:03	1542.46
13:00:31	1545.92	13:28:05	1514.39	13:55:39	1530.63
13:01:07	1539.03	13:28:41	1523.07	13:56:15	1528.54
13:01:43	1532.93	13:29:17	1546.83	13:56:51	1529.15
13:02:19	1531.59	13:29:53	1556.79	13:57:27	1526.71
13:02:55	1529.45	13:30:29	1567.5	13:58:03	1517.29
13:03:31	1522.97	13:31:05	1570.72	13:58:39	1515.54
13:04:07	1517.31	13:31:41	1559.43	13:59:15	1513.46
13:04:43	1514.11	13:32:17	1558.85	13:59:51	1520.17
13:05:19	1514.84	13:32:53	1558.8	14:00:27	1538.61
13:05:55	1520.18	13:33:29	1557.27	14:01:03	1554.4
13:06:31	1527.69	13:34:05	1555.6	14:01:39	1554.12
13:07:06	1538.51	13:34:41	1553.93	14:02:15	1554.73
13:07:42	1551.43	13:35:17	1551.62	14:02:51	1555.26
13:08:18	1568.34	13:35:53	1541.33	14:03:27	1549.32
13:08:54	1576.6	13:36:29	1539.14	14:04:03	1542.55
13:09:30	1567.74	13:37:04	1531.42	14:04:39	1540.98
13:10:06	1565.52	13:37:40	1527.56	14:05:15	1539.91
13:10:42	1563.96	13:38:16	1523.44	14:05:51	1539.78
13:11:18	1554.28	13:38:52	1514.91	14:06:27	1538.13
13:11:54	1553.32	13:39:28	1512.32	14:07:02	1529.42
13:12:30	1552.24	13:40:04	1513.59	14:07:38	1524.8
13:13:06	1545.65	13:40:40	1528.29	14:08:14	1515.33
13:13:42	1538.04	13:41:16	1547.55	14:08:50	1514.53
13:14:18	1531.52	13:41:52	1554.59	14:09:26	1518.01
13:14:54	1526.32	13:42:28	1556.7	14:10:02	1535.99
13:15:30	1516.27	13:43:04	1555.7	14:10:38	1550.72
13:16:06	1513.4	13:43:40	1555.02	14:11:14	1550.79
13:16:42	1514.22	13:44:16	1553.05	14:11:50	1545.1
13:17:18	1524.64	13:44:52	1544.86	14:12:26	1535.62
13:17:54	1541.47	13:45:28	1535.24	14:13:02	1529.48
13:18:30	1558.07	13:46:04	1534.7	14:13:38	1525.68
13:19:06	1560.21	13:46:40	1527.93	14:14:14	1514.88
13:19:42	1559.52	13:47:16	1526.32	14:14:50	1513.7

Table 1. Cont (e)

Time	Density	Time	Density	Time	Density
14:15:26	1515.88	14:43:00	1613.52	15:10:34	1642.76
14:16:02	1528.14	14:43:36	1601.23	15:11:10	1641.49
14:16:38	1561.81	14:44:12	1597.73	15:11:46	1640.13
14:17:14	1568.32	14:44:48	1594.25	15:12:22	1632.55
14:17:50	1557.94	14:45:24	1593.59	15:12:58	1631.12
14:18:26	1558.18	14:46:00	1585.3	15:13:34	1629.79
14:19:02	1555.92	14:46:36	1582.45	15:14:10	1626.76
14:19:38	1556.49	14:47:12	1581.75	15:14:46	1620.1
14:20:14	1556.02	14:47:48	1574.28	15:15:22	1612.22
14:20:50	1555.68	14:48:24	1569.78	15:15:58	1603.53
14:21:26	1550.04	14:49:00	1560.16	15:16:34	1596.14
14:22:01	1543.23	14:49:36	1552.86	15:17:10	1586.7
14:22:37	1537.92	14:50:12	1541.55	15:17:46	1577.42
14:23:13	1528.89	14:50:48	1538.76	15:18:22	1568.21
14:23:49	1525.98	14:51:24	1530.33	15:18:58	1563.21
14:24:25	1519.11	14:51:59	1523.89	15:19:34	1561.99
14:25:01	1515.97	14:52:35	1520.8	15:20:10	1550.79
14:25:37	1512.44	14:53:11	1515.33	15:20:46	1543.95
14:26:13	1511.67	14:53:47	1509.78	15:21:22	1537.67
14:26:49	1516.37	14:54:23	1508.79	15:21:57	1530.23
14:27:25	1531.43	14:54:59	1516.99	15:22:33	1521.37
14:28:01	1547.17	14:55:35	1539.54	15:23:09	1513.18
14:28:37	1562..37	14:56:11	1561.1	15:23:45	1512.23
14:29:13	1569.31	14:56:47	1570.26	15:24:21	1519.37
14:29:49	1573.25	14:57:23	1579.62	15:24:57	1530.3
14:30:25	1572.26	14:57:59	1586.85	15:25:33	1558.55
14:31:01	1570.36	14:58:35	1587.4	15:26:09	1569.79
14:31:37	1564.07	14:59:11	1586	15:26:45	1571.16
14:32:13	1557.66	14:59:47	1584.18	15:27:21	1576.17
14:32:49	1557.39	15:00:23	1564.69	15:27:57	1575.97
14:33:25	1557.44	15:00:59	1542.28	15:28:33	1569.29
14:34:01	1557.17	15:01:35	1533.94	15:29:09	1565.26
14:34:37	1556.64	15:02:11	1522.08	15:29:45	1557.01
14:35:13	1555.3	15:02:47	1520.29	15:30:21	1550.25
14:35:49	1551.1	15:03:23	1516.89	15:30:57	1547.64
14:36:25	1543.87	15:03:59	1511.1	15:31:33	1546.99
14:37:00	1529.51	15:04:35	1504.9	15:32:09	1540.65
14:37:36	1526.11	15:05:11	1499.99	15:32:45	1532.65
14:38:12	1521.3	15:05:47	1517.2	15:33:21	1526.54
14:38:48	1514.25	15:06:23	1521.46	15:33:57	1519.66
14:39:24	1512.46	15:06:58	1529.45	15:34:33	1513.74
14:40:00	1509.48	15:07:34	1545.4	15:35:09	1516.67
14:40:36	1512.16	15:08:10	1576.52	15:35:45	1520.25
14:41:12	1521.87	15:08:46	1610.76	15:36:21	1533.79
14:41:48	1557	15:09:22	1619.6	15:36:56	1548.99
14:42:24	1605.18	15:09:58	1635.18	15:37:32	1548.27

Table 1. Cont (f)

Time	Density	Time	Density	Time	Density
15:38:08	1541.54	16:05:43	1554		
15:38:44	1536.82	16:06:19	1551.15		
15:39:20	1529.14	16:06:54	1550.61		
15:39:56	1518.88	16:07:30	1550.99		
15:40:32	1512.68	16:08:06	1549.3		
15:41:08	1508.48	16:08:42	1544.41		
15:41:44	1514.94	16:09:18	1539.01		
15:42:20	1551.58	16:09:54	1531.55		
15:42:56	1597.5	16:10:30	1525.98		
15:43:32	1580.9	16:11:06	1521.31		
15:44:08	1577.17	16:11:42	1513.79		
15:44:44	1576.19	16:12:18	1509.34		
15:45:20	1575.9	16:12:54	1523.44		
15:45:56	1574.46	16:13:30	1539.94		
15:46:32	1572.2	16:14:06	1556.73		
15:47:08	1571.52	16:14:42	1557.62		
15:47:44	1570.77	16:15:18	1554.25		
15:48:20	1560.67	16:15:54	1547.7		
15:48:56	1554.55	16:16:30	1543.48		
15:49:32	1549.06	16:17:06	1530.16		
15:50:08	1543.45	16:17:42	1523.43		
15:50:44	1537.69	16:18:18	1521.88		
15:51:20	1531.33	16:18:54	1520.07		
15:51:55	1523.09	16:19:30	1511.82		
15:52:31	1511.24	16:20:06	1511.38		
15:53:07	1513.81	16:20:42	1516.9		
15:53:43	1521.84	16:21:18	1547.85		
15:54:19	1539.68	16:21:53	1594.85		
15:54:55	1557.55				
15:55:31	1558.06				
15:56:07	1557.15				
15:56:43	1555.45				
15:57:19	1553.53				
15:57:55	1544.92				
15:58:31	1531.07				
15:59:07	1529.55				
15:59:43	1525.89				
16:00:19	1517.64				
16:00:55	1514.72				
16:01:31	1514.73				
16:02:07	1515.93				
16:02:43	1546.66				
16:03:19	1562.99				
16:03:55	1554.84				
16:04:31	1554.78				
16:05:07	1554.41				

In table 2 set out below, the normalised frequency distribution of the densities given in Table 1 are set out.

The normalised frequency is obtained by multiplying the frequency value by 100 and dividing by the sum of the normalised frequency column. The cumulative normalised frequency is the addition of the particular normalised frequency by the sum of the previous normalised frequencies.

TABLE 2

Frequency Distribution					
Density Range			Frequency	Normalised Frequency	Cumulative Normalised frequency
Lower	Upper	Mean Density			
kg/m3	kg/m3				
	1442		0	0.000	0.000
1442	1443	1442.5	1	0.111	0.111
1443	1444	1443.5	0	0.000	0.111
1444	1445	1444.5	0	0.000	0.111
1445	1446	1445.5	0	0.000	0.111
1446	1447	1446.5	1	0.111	0.222
1447	1448	1447.5	0	0.000	0.222
1448	1449	1448.5	0	0.000	0.222
1449	1450	1449.5	0	0.000	0.222
1450	1451	1450.5	0	0.000	0.222
1451	1452	1451.5	0	0.000	0.222
1452	1453	1452.5	0	0.000	0.222
1453	1454	1453.5	0	0.000	0.222
1454	1455	1454.5	0	0.000	0.222
1455	1456	1455.5	1	0.111	0.333
1456	1457	1456.5	0	0.000	0.333
1457	1458	1457.5	0	0.000	0.333
1458	1459	1458.5	0	0.000	0.333
1459	1460	1459.5	0	0.000	0.333
1460	1461	1460.5	0	0.000	0.333
1461	1462	1461.5	0	0.000	0.333
1462	1463	1462.5	0	0.000	0.333
1463	1464	1463.5	1	0.111	0.443
1464	1465	1464.5	1	0.111	0.554
1465	1466	1465.5	0	0.000	0.554
1466	1467	1466.5	0	0.000	0.554
1467	1468	1467.5	0	0.000	0.554
1468	1469	1468.5	0	0.000	0.554
1469	1470	1469.5	0	0.000	0.554
1470	1471	1470.5	0	0.000	0.554
1471	1472	1471.5	1	0.111	0.665
1472	1473	1472.5	0	0.000	0.665
1473	1474	1473.5	1	0.111	0.776
1474	1475	1474.5	0	0.000	0.776
1475	1476	1475.5	0	0.000	0.776
1476	1477	1476.5	0	0.000	0.776
1477	1478	1477.5	0	0.000	0.776
1478	1479	1478.5	0	0.000	0.776
1479	1480	1479.5	0	0.000	0.776
1480	1481	1480.5	1	0.111	0.887

1481	1482	1481.5	0	0.000	0.887
1482	1483	1482.5	0	0.000	0.887
1483	1484	1483.5	0	0.000	0.887
1484	1485	1484.5	0	0.000	0.887
1485	1486	1485.5	0	0.000	0.887
1486	1487	1486.5	1	0.111	0.998
1487	1488	1487.5	0	0.000	0.998
1488	1489	1488.5	1	0.111	1.109
1489	1490	1489.5	0	0.000	1.109
1490	1491	1490.5	1	0.111	1.220
1491	1492	1491.5	1	0.111	1.330
1492	1493	1492.5	0	0.000	1.330
1493	1494	1493.5	0	0.000	1.330
1494	1495	1494.5	0	0.000	1.330
1495	1496	1495.5	0	0.000	1.330
1496	1497	1496.5	0	0.000	1.330
1497	1498	1497.5	0	0.000	1.330
1498	1499	1498.5	1	0.111	1.441
1499	1500	1499.5	1	0.111	1.552
1500	1501	1500.5	0	0.000	1.552
1501	1502	1501.5	3	0.333	1.885
1502	1503	1502.5	3	0.333	2.217
1503	1504	1503.5	0	0.000	2.217
1504	1505	1504.5	3	0.333	2.550
1505	1506	1505.5	1	0.111	2.661
1506	1507	1506.5	0	0.000	2.661
1507	1508	1507.5	2	0.222	2.882
1508	1509	1508.5	11	1.220	4.102
1509	1510	1509.5	7	0.776	4.878
1510	1511	1510.5	9	0.998	5.876
1511	1512	1511.5	9	0.998	6.874
1512	1513	1512.5	14	1.552	8.426
1513	1514	1513.5	18	1.996	10.421
1514	1515	1514.5	20	2.217	12.639
1515	1516	1515.5	14	1.552	14.191
1516	1517	1516.5	12	1.330	15.521
1517	1518	1517.5	10	1.109	16.630
1518	1519	1518.5	11	1.220	17.849
1519	1520	1519.5	11	1.220	19.069
1520	1521	1520.5	15	1.663	20.732
1521	1522	1521.5	19	2.106	22.838
1522	1523	1522.5	10	1.109	23.947
1523	1524	1523.5	12	1.330	25.277
1524	1525	1524.5	11	1.220	26.497
1525	1526	1525.5	13	1.441	27.938
1526	1527	1526.5	17	1.885	29.823
1527	1528	1527.5	6	0.665	30.488
1528	1529	1528.5	13	1.441	31.929
1529	1530	1529.5	15	1.663	33.592

1530	1531	1530.5	13	1.441	35.033
1531	1532	1531.5	16	1.774	36.807
1532	1533	1532.5	11	1.220	38.027
1533	1534	1533.5	14	1.552	39.579
1534	1535	1534.5	4	0.443	40.022
1535	1536	1535.5	5	0.554	40.576
1536	1537	1536.5	8	0.887	41.463
1537	1538	1537.5	8	0.887	42.350
1538	1539	1538.5	13	1.441	43.792
1539	1540	1539.5	16	1.774	45.565
1540	1541	1540.5	11	1.220	46.785
1541	1542	1541.5	13	1.441	48.226
1542	1543	1542.5	9	0.998	49.224
1543	1544	1543.5	10	1.109	50.333
1544	1545	1544.5	13	1.441	51.774
1545	1546	1545.5	9	0.998	52.772
1546	1547	1546.5	9	0.998	53.769
1547	1548	1547.5	10	1.109	54.878
1548	1549	1548.5	15	1.663	56.541
1549	1550	1549.5	13	1.441	57.982
1550	1551	1550.5	14	1.552	59.534
1551	1552	1551.5	10	1.109	60.643
1552	1553	1552.5	8	0.887	61.530
1553	1554	1553.5	8	0.887	62.417
1554	1555	1554.5	22	2.439	64.856
1555	1556	1555.5	15	1.663	66.519
1556	1557	1556.5	11	1.220	67.738
1557	1558	1557.5	19	2.106	69.845
1558	1559	1558.5	9	0.998	70.843
1559	1560	1559.5	9	0.998	71.840
1560	1561	1560.5	9	0.998	72.838
1561	1562	1561.5	12	1.330	74.169
1562	1563	1562.5	7	0.776	74.945
1563	1564	1563.5	12	1.330	76.275
1564	1565	1564.5	11	1.220	77.494
1565	1566	1565.5	9	0.998	78.492
1566	1567	1566.5	8	0.887	79.379
1567	1568	1567.5	12	1.330	80.710
1568	1569	1568.5	10	1.109	81.818
1569	1570	1569.5	13	1.441	83.259
1570	1571	1570.5	12	1.330	84.590
1571	1572	1571.5	9	0.998	85.588
1572	1573	1572.5	5	0.554	86.142
1573	1574	1573.5	5	0.554	86.696
1574	1575	1574.5	7	0.776	87.472
1575	1576	1575.5	4	0.443	87.916
1576	1577	1576.5	7	0.776	88.692
1577	1578	1577.5	5	0.554	89.246
1578	1579	1578.5	5	0.554	89.800

1579	1580	1579.5	4	0.443	90.244
1580	1581	1580.5	5	0.554	90.798
1581	1582	1581.5	6	0.665	91.463
1582	1583	1582.5	3	0.333	91.796
1583	1584	1583.5	2	0.222	92.018
1584	1585	1584.5	1	0.111	92.129
1585	1586	1585.5	3	0.333	92.461
1586	1587	1586.5	4	0.443	92.905
1587	1588	1587.5	4	0.443	93.348
1588	1589	1588.5	2	0.222	93.570
1589	1590	1589.5	0	0.000	93.570
1590	1591	1590.5	2	0.222	93.792
1591	1592	1591.5	3	0.333	94.124
1592	1593	1592.5	0	0.000	94.124
1593	1594	1593.5	2	0.222	94.346
1594	1595	1594.5	3	0.333	94.678
1595	1596	1595.5	1	0.111	94.789
1596	1597	1596.5	1	0.111	94.900
1597	1598	1597.5	2	0.222	95.122
1598	1599	1598.5	1	0.111	95.233
1599	1600	1599.5	0	0.000	95.233
1600	1601	1600.5	0	0.000	95.233
1601	1602	1601.5	4	0.443	95.676
1602	1603	1602.5	2	0.222	95.898
1603	1604	1603.5	2	0.222	96.120
1604	1605	1604.5	0	0.000	96.120
1605	1606	1605.5	1	0.111	96.231
1606	1607	1606.5	0	0.000	96.231
1607	1608	1607.5	1	0.111	96.341
1608	1609	1608.5	1	0.111	96.452
1609	1610	1609.5	0	0.000	96.452
1610	1611	1610.5	3	0.333	96.785
1611	1612	1611.5	2	0.222	97.007
1612	1613	1612.5	1	0.111	97.118
1613	1614	1613.5	1	0.111	97.228
1614	1615	1614.5	2	0.222	97.450
1615	1616	1615.5	1	0.111	97.561
1616	1617	1616.5	0	0.000	97.561
1617	1618	1617.5	0	0.000	97.561
1618	1619	1618.5	2	0.222	97.783
1619	1620	1619.5	1	0.111	97.894
1620	1621	1620.5	2	0.222	98.115
1621	1622	1621.5	0	0.000	98.115
1622	1623	1622.5	3	0.333	98.448
1623	1624	1623.5	2	0.222	98.670
1624	1625	1624.5	0	0.000	98.670
1625	1626	1625.5	0	0.000	98.670
1626	1627	1626.5	1	0.111	98.780
1627	1628	1627.5	2	0.222	99.002

1628	1629	1628.5	0	0.000	99.002
1629	1630	1629.5	2	0.222	99.224
1630	1631	1630.5	1	0.111	99.335
1631	1632	1631.5	1	0.111	99.446
1632	1633	1632.5	1	0.111	99.557
1633	1634	1633.5	0	0.000	99.557
1634	1635	1634.5	0	0.000	99.557
1635	1636	1635.5	1	0.111	99.667
1636	1637	1636.5	0	0.000	99.667
1637	1638	1637.5	0	0.000	99.667
1638	1639	1638.5	0	0.000	99.667
1639	1640	1639.5	0	0.000	99.667
1640	1641	1640.5	1	0.111	99.778
1641	1642	1641.5	1	0.111	99.889
1642	1643	1642.5	1	0.111	100.000
1643	1644	1643.5	0	0.000	100.000
1644	1645	1644.5	0	0.000	100.000
1645					
			Total = 902	Total = 100.000	

The processor 50 then lines up the measured density values from lowest to highest so that the frequency of each measured value can be determined.

A chart is then prepared whereby the mid point of each density range is plotted against the density to give the partition coefficient curve.

The processor 50 then determines an induced value, which in the preferred embodiment uses the density measurements, is a medium induced Ep value from the cumulative frequency distribution of the length of time spent at each density by taking the absolute value of the difference in density at the 75th and 25th percentiles and dividing by 2000 as shown by the following equation:

Equation
Ep = absolute value (Density at 75th percentile - Density at 25th percentile)/2000

By way of further explanation, the inefficiency of the

processing is generally given by the Ep value. Figure 3 is a graph in an ideal situation where perfect separation results in correct placement of all material in the feed that should report to product reporting to product and all material in feed that should report to reject reporting to reject. If the above equation is applied to the data in Figure 3, it will be seen that the Ep value is 0, which gives a theoretically perfect result. However, in real operating conditions, the graph of Figure 3 is more likely to look like that shown in Figure 4 Using the data supplied in Table 2 and Figure 4, the Ep value is (1562.5 - 1523.5)/2000, which equals 0.0195. The processor 50 is programmed to generate an alarm, should the calculated Ep value become, for example, 0.025. Thus, the graph shown in Figure 4 is indicative of a acceptable MIEp value in this context indicating that remedial action does not need to be taken. If the value was above 0.025, an alarm condition would be generated. As shown in Figure 2, the processor may output a signal to an alarm 52 to generate the alarm, which could be an audible alarm or simply a visual indication on a monitor or a combination of both to alert operators in the control room that fluctuations have exceeded a desired value and that remedial action should be taken to correct the situation to restore the proper medium density, and thereby restore maximum yield operation to the processing plant.

The remedial action which may be taken may be to dispatch workmen to inspect valves in the system to ensure that they are operating properly and have not jammed or closed, pipelines to ensure that there are no leakages, and other operating parameters of the equipment. Action can be taken by workmen to correct any fault which may be observed immediately, rather than awaiting routine inspections or the like which may result in a fault continuing for a continued period of time, and thereby resulting in significant loss in the yield from the plant until the remedial action is identified and taken.

The remedial action may also take the form of an automated response, for example the remedial action may be to invoke a control system retune algorithm to optimise PID control system values.

MIEp values are periodically determined after an initial period of 9 hours by simply dropping off the first measurement made and adding to the total of measurements the next successive measurement made. For example, in Table 1, the next MIEp value may be calculated by dropping off the density reading for the time 7:21:54 and adding to the list of density values measured that for time period 16:21:53. This would provide a new MIEp value for comparison with the predetermined value every 36 seconds. Obviously, if a greater period is desired, then additional earlier readings can be ignored and more subsequent measurements made before a further MIEp value is calculated. Also, if measurements of MIEp over a shorter period are desired, density data would be collected for the shorter period and used in a manner similar to that presented above.

An additional example is given with the same data as shown in Table 1 for the situation where measurements of MIEp over a shorter period are required. For a rolling period of 90 minutes a rolling MIEp can be calculated. It is then possible to plot rolling MIEp as ordinate and time as abscissa.

In accordance with the preferred embodiment of the invention, the processing plant can be monitored to determine when its separating performance drops below required levels, thereby enabling remedial action to be immediately taken, and this could be worth millions of dollars per annum to the operation. The monitoring can take the form of a run chart of MIEp in which upper and lower control limits can be derived. Derivation above the

upper control limit can be used as the signal for corrective action in the processor 50. Also, the run charts of MIEp can be used as a benchmarking tool to compare control systems within a given plant, and also between plants.

In the second embodiment of the invention in which the pressure measurements are taken so as to produce a pressure induced Ep value, a similar algorithm to that described above is used with the inclusion of a theoretically and/or empirically determined relationship between pressure and separating density. Alternatively, the pseudo PIEp concept can be used. The pressure values are measured at the time intervals similar to that in Figure 1. The separating density is a function of the pressure and therefore the pressure values can be converted to separating density values via an appropriate empirical or theoretical calibration which are accumulated in the same manner as described with reference to Table 2 so as to enable the Ep value to be calculated.

Similarly, in the embodiment which uses feed rate, the feed rate of material is measured as, for example, weight in tonnes per hour, and these values are again converted to separation density values so that an accumulation of separation densities can be used to enable the feed rate induced Ep value to be determined. Alternatively, the pseudo FRIEp concept can be used.

Similarly, in the embodiment which uses Medium to Coal Ratio, the Medium to Coal Ratio is measured as, for example, cubic meters of medium per hours divided by weight in tonnes per hour of dense medium cyclone feed, and these values are again converted to separation density values so that an accumulation of separation densities can be used to enable the Medium to Coal Ratio induced Ep value to be determined. Alternatively, the pseudo MCRIEp concept can be used.

For the example given above, the detailed calculations presented indicated that the medium induced Ep was 0.0195. Following similar lines, it is possible to calculate a pressure induced Ep = 0.002. At the same time, the measured Ep for coal was 0.026. This is interpreted as about 70% of the Ep was due to medium density variation and about 7% was due to pressure variation.

The additional interpretation of the invention is that the large proportion of the actual separating inefficiencies of the dense medium separator is due to process variation and can be measured with relative ease in most modern processing facilities. Also, if the MIEp=0.0195 then the Ep of the coal cannot be smaller than 0.0195, and so the invention also permits the lower limit of coal separating efficiency to be measured with relative ease on-line.

Since modifications within the spirit and scope of the invention may readily be effected by persons skilled within the art, it is to be understood that this invention is not limited to the particular embodiment described by way of example hereinabove.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise", or variations such as "comprises" or "comprising", is used in an inclusive sense, ie. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

Claims

1. A method of processing particulate material, including the steps of:

supplying the particulate material to a separator;

monitoring a parameter of the separator indicative of a separation value of the material;

determining from said parameter an induced value indicative of the separating efficiency of the material that passed through said separator;

comparing said value with a predetermined value; and

generating an alarm condition if the said value departs from the predetermined value by a predetermined amount.

2. The method of claim 1 wherein the separator is a medium dense separator and the separation value comprises the separating density of the separator.

3. The method of claim 1 wherein the separator is a classifying separator and the separation value is the separation size of the material at which separation is to take place.

4. The method of claim 1 wherein the separator comprises a heavy medium device containing a dense medium.

5. The method of claim 1 wherein the step of determining the induced value comprises determining an induced set of values indicative of the separating efficiency of the material that passed through the device, the step of comparing said value comprises comparing said set of values with a predetermined range for the set of values, and the step of generating the alarm condition comprises generating the alarm condition if the said set of values departs from the predetermined range for the set

of values by a predetermined amount.

6. The method of claim 5 wherein the set of values is in the form of a partition coefficient curve and parameters derived therefrom.

7. The method of claim 1 wherein the parameter which is monitored is the actual density of the medium.

8. The method of claim 1 wherein the parameter is pressure of the medium and particle mixture which is supplied to the device.

9. The method of claim 1 wherein the parameter is the feed rate of the medium and particle mixture supplied to the device.

10. The method of claim 1 wherein the parameter is the overall processing plant feed rate.

11. The method of claim 1 wherein the parameter is the ratio of volume or mass flow rate of medium to the volume of mass flow rate of the material.

12. The method of claim 1 wherein the parameter is two or more of the medium density, pressure of the medium and particle mixture, feed rate of the medium and particle mixture, and ratio of volume or mass flow rate of medium to the volume of mass flow rate of the material.

13. The method of claim 7 wherein the density of the medium is measured at predetermined time intervals, and for a predetermined time period, the number of measurements at each measured value is determined to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and said set of values characterising separating efficiency is determined as a medium induced partition

coefficient curve and/or a parameter derived therefrom, for example medium induced Ep value (MIEp value) by taking the absolute value of the difference in density at the 75th and 25th percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the MIEp value with the said predetermined value, or medium induced partition coefficient curve with a predetermined partition coefficient curve.

14. The method according to claim 8 wherein a pressure induced partition coefficient curve is derived by taking the absolute value of the difference in pressure at the 75th and 25th percentiles, and dividing by 2000 so as to produce a PIEp value which is a theoretical value dependent on pressure variations and comparing the PIEp value with the said predetermined value, or pressure induced partition coefficient curve with a predetermined partition coefficient curve.

15. The method according to claim 14 wherein a pseudo PIEp value is used as the PIEp value to avoid the need for calibration.

16. The method according to claim 10 wherein a feed rate induced partition coefficient curve is derived by taking the absolute value of the difference in feed rate at the 75th and 25th percentiles, and dividing by 2000 so as to produce a FRIEp value which is a theoretical value dependent on feed rate variations and comparing the FRIEp value with the said predetermined value, or feed rate induced partition coefficient curve with a predetermined partition coefficient curve.

17. The method according to claim 16 wherein a pseudo FRIEp value is used as the FRIEp value to avoid the need for calibration.

18. The method according to claim 11 wherein a ratio of medium to material induced partition coefficient curve is derived by taking the absolute value of the difference in ratio at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a MCRIEp value which is a theoretical value dependent on ratio variations and comparing the MCRIEp value with the said predetermined value, or ratio induced partition coefficient curve with a predetermined partition coefficient curve.

19. The method according to claim 18 wherein a pseudo MCRIEp value is used as the MCRIEp value to avoid the need for calibration.

20. An apparatus for processing particulate material, comprising:

means for supplying the particulate material to a separator;

means for monitoring a parameter of the separator indicative of a separation value of the material;

processing means for determining from said parameter an induced value indicative of the separating efficiency of the material that passed through said separator;

comparing means for comparing said value with a predetermined value; and

alarm means for producing an alarm condition if the said value departs from the predetermined value set by a predetermined amount.

21. The apparatus of claim 20 wherein the separator comprises a heavy medium device.

22. The apparatus of claim 20 wherein the processing means is for determining from said parameter an induced set of values indicative of the separating efficiency of the material that passed through the device, the comparing means is for comparing the said value set with a

predetermined value set and the alarm means is for producing the alarm condition if the set of values departs from the predetermined value set by a predetermined amount.

23. The apparatus of claim 20 wherein the parameter is density of medium, and the monitoring means is for measuring the density of the medium at predetermined time intervals, and for a predetermined time period, and the processing means is for determining the number of measurements at each measured value to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and for determining said value set as a medium induced partition coefficient curve and/or parameters derived therefrom by taking the absolute value of the difference in relative density at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the partition coefficient curve and parameters derived therefrom with the said predetermined value set.

24. The apparatus according to claim 20 wherein the parameter is feed rate and the processing means is for determining a feed rate induced partition coefficient curve by taking the absolute value of the difference in feed rate at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a FRIEp value which is a theoretical value dependent on feed rate variations and comparing the FRIEp value with the said predetermined value, or feed rate induced partition coefficient curve with a predetermined partition coefficient curve.

25. The apparatus according to claim 24 wherein a pseudo FRIEp value is used as the FRIEp value to avoid the need for calibration.

26. The apparatus according to claim 20 wherein the parameter is pressure and the processing means is for determining a pressure induced partition coefficient curve by taking the absolute value of the difference in pressure at the 75th and 25th percentiles, and dividing by 2000 so as to produce a PIEp value which is a theoretical value dependent on pressure variations and comparing the PIEp value with the said predetermined value, or pressure induced partition coefficient curve with a predetermined partition coefficient curve.

27. The apparatus according to claim 26 wherein a pseudo PIEp value is used as the PIEp value to avoid the need for calibration.

28. The apparatus according to claim 20 wherein the parameter is material to medium ratio and the processing means is for determining a ratio induced partition coefficient curve by taking the absolute value of the difference in ratio at the 75th and 25th percentiles, and dividing by 2000 so as to produce a MCRIEp value which is a theoretical value dependent on ratio variations and comparing the MCRIEp value with the said predetermined value, or ratio induced partition coefficient curve with a predetermined partition coefficient curve.

29. The method according to claim 28 wherein a pseudo MCRIEp value is used as the MCRIEp value to avoid the need for calibration.

30. A method of determining the efficiency of separation of particulate material supplied to a separator, comprising the steps of:

monitoring a parameter of the separator indicative of a separation value of the material;

determining from said parameter an induced value indicative of the separating efficiency of the material that pass through the separator; and

using the induced value to provide a measure of the efficiency of separation.

31. The method of claim 30 wherein the step of determining the induced value comprises determining an induced set of values indicative of the separating efficiency of the material that passed through the device, the step of comparing said value comprises comparing said set of values with a predetermined range for the set of values, and the step of generating the alarm condition comprises generating the alarm condition if the said set of values departs from the predetermined range for the set of values by a predetermined amount.

32. The method of claim 31 wherein the set of values may be in the form of a partition coefficient curve and parameters derived therefrom.

33. The method of claim 31 wherein the parameter which is monitored is the actual density of the medium.

34. The method of claim 31 wherein the parameter is pressure of the medium and particle mixture which is supplied to the device.

35. The method of claim 31 wherein the parameter is the feed rate of the medium and particle mixture supplied to the device.

36. The method of claim 31 wherein the parameter is the overall processing plant feed rate.

37. The method of claim 30 wherein the parameter is the ratio of volume or mass flow rate of medium to the volume of mass flow rate of the material.

38. The method of claim 30 wherein the parameter is two or more of the medium density, pressure of the medium

and particle mixture, feed rate of the medium and particle mixture, and the ratio of volume or mass flow rate of medium to the volume of mass flow rate of the material.

39. The method of claim 33 wherein the density of the medium is measured at predetermined time intervals, and for a predetermined time period, the number of measurements at each measured value is determined to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and said set of values characterising separating efficiency is determined as a medium induced partition coefficient curve and/or a parameter derived therefrom, for example medium induced Ep value (MIEp value) by taking the absolute value of the difference in density at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the MIEp value with the said predetermined value, or medium induced partition coefficient curve with a predetermined partition coefficient curve.

40. The method according to claim 36 wherein a feed rate induced partition coefficient curve is derived by taking the absolute value of the difference in feed rate at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a FRIEp value which is a theoretical value dependent on feed rate variations and comparing the FRIEp value with the said predetermined value, or feed rate induced partition coefficient curve with a predetermined partition coefficient curve.

41. The method according to claim 40 wherein a pseudo FRIEp value is used as the FRIEp value to avoid the need for calibration.

42. The method according to claim 34 wherein a pressure induced partition coefficient curve is derived by

taking the absolute value of the difference in pressure at the 75th and 25th percentiles, and dividing by 2000 so as to produce a PIEp value which is a theoretical value dependent on pressure variations and comparing the PIEp value with the said predetermined value, or pressure induced partition coefficient curve with a predetermined partition coefficient curve.

43. The method according to claim 42 wherein a pseudo PIEp value is used as the PIEp value to avoid the need for calibration.

44. The method according to claim 37 wherein a ratio of material to medium induced partition coefficient curve is derived by taking the absolute value of the difference in ratio at the 75th and 25th percentiles, and dividing by 2000 so as to produce a MCRIEp value which is a theoretical value dependent on ratio variations and comparing the MCRIEp value with the said predetermined value, or ratio induced partition coefficient curve with a predetermined partition coefficient curve.

45. The method according to claim 44 wherein a pseudo MCRIEp value is used as the MCRIEp value to avoid the need for calibration.

46. The use of the measure of efficiency determined according to claim 18 to adjust a processing plant to more efficiently separate the material.

47. An apparatus for processing particulate material, comprising:

means for supplying the particulate material to a separator;

means for monitoring a parameter of the separator indicative of a separation value of the material; and

processing means for determining from said parameter an induced value indicative of the separating

efficiency of the material that pass through said separator to thereby provide a measure of the efficiency of the apparatus.

48. The apparatus of claim 47 wherein the separator comprises a heavy medium device.

49. The apparatus of claim 47 wherein the processing means is for determining from said parameter an induced set of values indicative of the separating efficiency of the material that passed through the device, the comparing means is for comparing the said value set with a predetermined value set and the alarm means is for producing the alarm condition if the set of values departs from the predetermined value set by a predetermined amount.

50. The apparatus of claim 47 wherein the parameter is the density of the medium, and the monitoring means is for measuring the density of the medium at predetermined time intervals, and for a predetermined time period, and the processing means is for determining the number of measurements at each measured value to produce a cumulative normalised frequency distribution of the length of time the particle spends at each measured density, and for determining said value set as a medium induced partition coefficient curve and/or parameters derived therefrom by taking the absolute value of the difference in relative density at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce an MIEp value which is a theoretical value solely dependent on medium density variations, and comparing the partition coefficient curve and parameters derived therefrom with the said predetermined value set.

51. The apparatus according to claim 47 wherein the parameter is pressure and the processing means is for determining a pressure induced partition coefficient curve

is derived by taking the absolute value of the difference in pressure at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a PIEp value which is a theoretical value dependent on pressure variations and comparing the PIEp value with the said predetermined value, or pressure induced partition coefficient curve with a predetermined partition coefficient curve.

52. The method according to claim 51 wherein a pseudo PIEp value is used as the PIEp value to avoid the need for calibration.

53. The method according to claim 47 wherein the parameter is feed rate and the processing means is for determining a feed rate induced partition coefficient curve by taking the absolute value of the difference in feed rate at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a FRIEp value which is a theoretical value dependent on feed rate variations and comparing the FRIEp value with the said predetermined value, or feed rate induced partition coefficient curve with a predetermined partition coefficient curve.

54. The method according to claim 53 wherein a pseudo FRIEp value is used as the FRIEp value to avoid the need for calibration.

55. The method according to claim 47 wherein the parameter is ratio of medium to material and the processing means is for determining a ratio induced partition coefficient curve by taking the absolute value of the difference in ratio at the 75^{th} and 25^{th} percentiles, and dividing by 2000 so as to produce a MCRIEp value which is a theoretical value dependent on ratio variations and comparing the MCRIEp value with the said predetermined value, or ratio induced partition coefficient curve with a predetermined partition coefficient curve.

56. The method according to claim 55 wherein a pseudo MCRIEp value is used as the MCRIEp value to avoid the need for calibration.

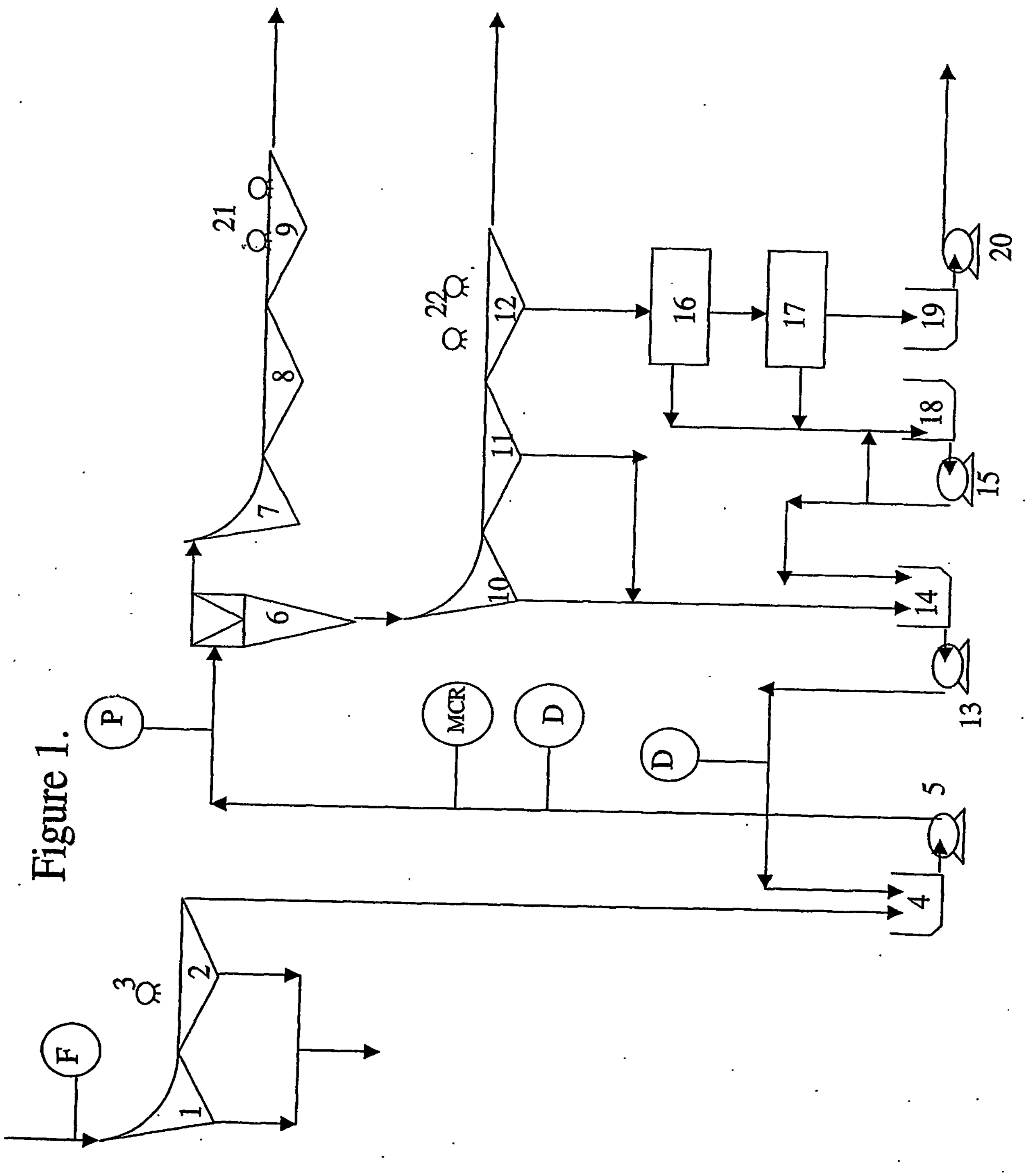


Figure 1.

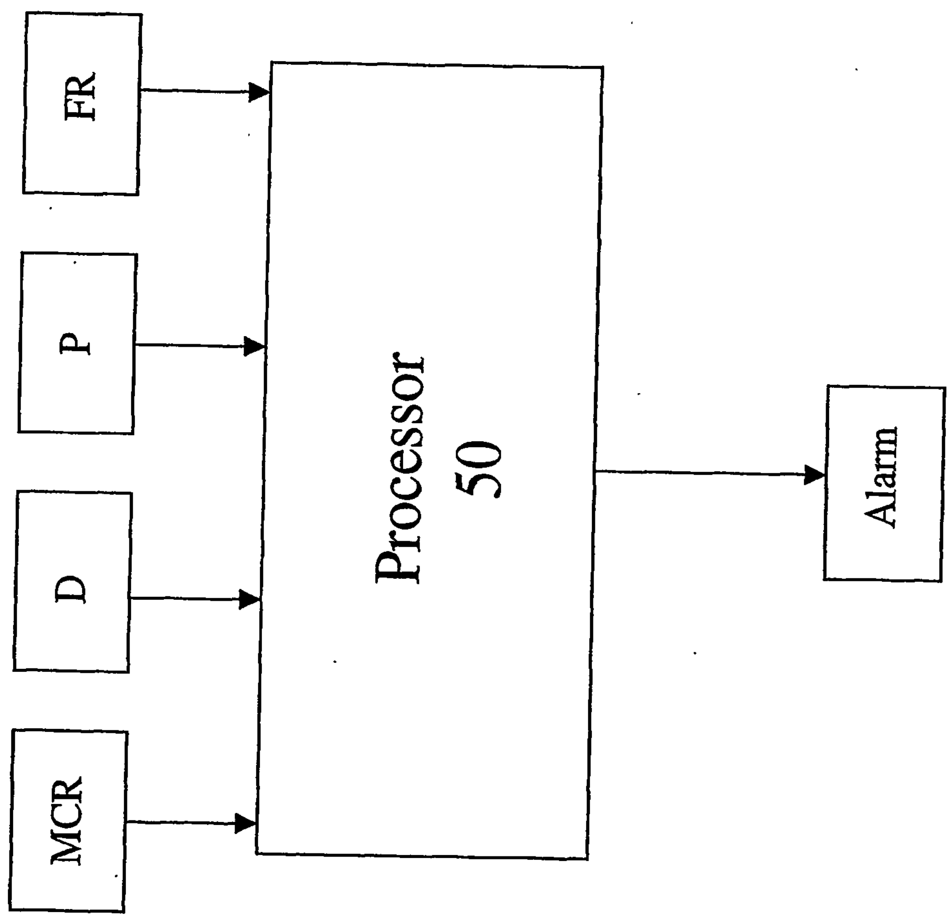


Figure 2

Figure 3.

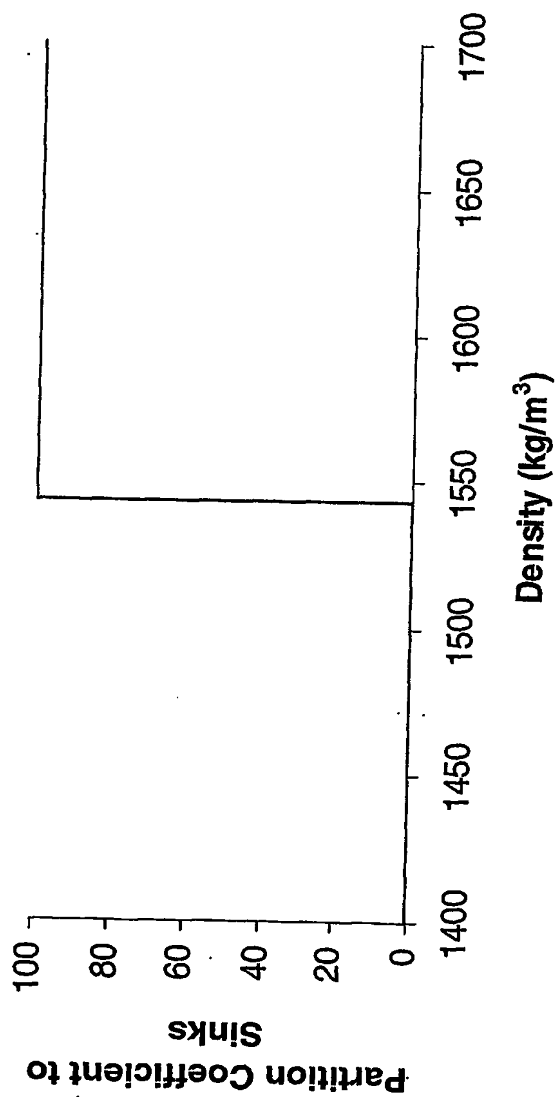
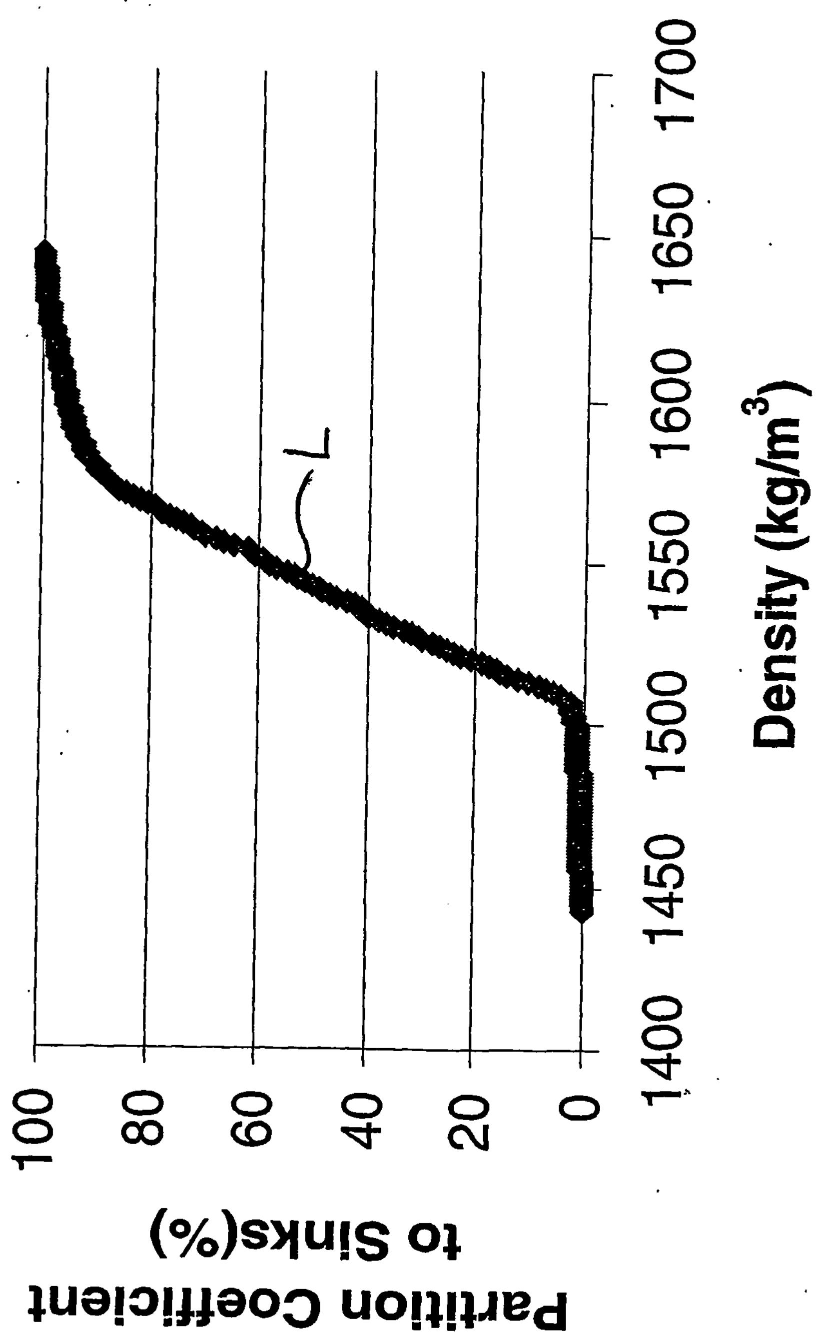

Partition Coefficient to Sinks
100
80
60
40
20
0
1400
1450
1500
1550
1600
1650
1700
Density (kg/m3)

Figure 4.


Partition Coefficient to Sinks(%)
100
80
60
40
20
0
1400
1450
1500
1550
1600
1650
1700
Density (kg/m3)
L

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2003/001727

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: B03B 13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B03B 13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI IPC B03B 13/00 and Keywords (density);
USPTO and Keywords ("set point" and thickener and control and monitor and efficiency)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2075867 A (NORTON-HARTY COLLIERY ENGINEERING LIMITED) 25 November 1981 See whole document	1-5, 8, 20-22, 30-32, 34, 47-49
X	US 4226714 A (FURNESS ET AL.) 7 October 1980 See whole document	1-5, 7, 12, 20-22, 30-33, 38, 47-49
X	US 6212943 B (MALTBY ET AL.) 10 April 2001 See figure 2 and column 5 line 53 to column 6 line 67	1-5, 7, 20-22, 30-33, 47-49

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 18 February 2004	Date of mailing of the international search report 23 FEB 2004
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2003/001727

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4470901 A (BURGESS) 11 September 1984 See whole document	1-4, 12, 20-21, 30, 32, 38, 47-48
X	GB 2188752 A (CENTURY AUTOFLOTE PTY. LTD.) 7 October 1987 See whole document	1-4, 12, 20-21, 30, 32, 38, 47-48
X	Derwent Abstract Accession No. 1999-494977/42, Class J01, DE 19751591 A (DOBERSEK A), 2 September 1999	1-4, 7, 20-21, 30, 32-33, 47-48

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2003/001727

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	2075867	EP	0040519				
US	4226714	AU	53835/79	CA	1142453	ZA	7906718
US	6212943	CA	2270398	EP	1009980	US	6062070
		WO	9819139				
US	4470901	AU	17362/83	CA	1204081		
GB	2188752	AU	70053/87	US	4731176	ZA	8702013
DE	19751591						

END OF ANNEX